TITLE: Multi-Sensor-Integration Concept for Airborne Surveillance Applications

Multi-Sensor-Integration Concept for Airborne Surveillance Applications

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1 ABSTRACT

Modern airborne surveillance systems have to cope with an immense number of inputs from real wanted and unwanted ground, maritime and/or airborne targets as well as correlated clutter. This causes significant challenges for tracking, classification, and identification of the detected objects. A state of the art multi-sensor integration (MSI) system calls for real-time integration of all available information pertaining to a real world object, in particular, geometric, kinematic, and signature data. The MSI system provide by DaimlerChrysler Aerospace yields improved tracking quality and performs automatic identification of targets.

The multi-sensor integration system processes data of various sensors, e.g., primary surveillance radar, secondary surveillance radar (IFF), data of passive electronic support measurements (ESM), acoustic sensor systems, crosstold data of Link-11 and Link-16 etc.. Based upon these data, the system will perform two tasks: Multi-sensor tracking and multi-sensor identification.

New tracks will be initiated automatically based upon data input from active or passive sensors, respectively. State of the art multi-model technology is used. It guarantees optimal track stability under various maneuver conditions. In the correlation function, either an improved nearest neighbor algorithm or the advanced multi-hypothesis concepts are applied.. ESM reports from tactical data links and specific sensors are used to perform multi-sensor cooperative passive tracking.

The multi-sensor identification system (MSI) is capable to identify air, surface, and ground tracks. It will operate fully automatically using all available data from all sensors as well as derived and background information depending on the confidence which is associated with the particular source. The system is able to handle various identification schemes in parallel. The automatic identification process will evaluate all available identification information for every MSI track using ''identification indicators''. The identification indicators will be combined to yield a track identity using an artificial intelligence (AI) supported combination process. Both, the MSI tracking and MSI identification functions can be controlled by mission data which are provided at mission startup or at any time during the mission.

2 THE MULTI-SENSOR INTEGRATION SYSTEM

2.1 MSI System Overview

The ultimate goal of all multi-sensor integration systems is to generate a precise picture of the according real world scenario. The system has to merge all available inputs that pertain to one target to only one object in the picture on the display. This picture must contain only real and no false targets, all correctly identified at the correct locations. This goal can only be achieved by a careful harmonization of the sensor integration software with the high performance of the contributing sensors. The term Multi-Sensor Integration comprises essentially two distinct functions, which are Multi-Sensor Tracking including the correlation function and the Multi-Sensor Identification.

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Our MSI will provide multi sensor tracking and identification functionality. The MSICP (Multi-Sensor Integration Computer Program) will consist of the following parts:

- MSI Tracking
- MSI Identification
- MSI Manager

The MSI Tracking and Identification functions provide the basic operational functionality of the MSICP. The MSI Manager includes functionality mainly in the area of control and monitoring, communication, redundancy support and test and maintenance provisions for the MSICP.

2.2 The Multi-Sensor Tracking System

The Multi-Sensor Tracking has the capability to use sensor inputs from a wide variety of different sensors which are the primary radar, the SSR/IFF sensor, etc., the ESM system and crosstold sensor inputs via the various tactical data links. It is based upon Multi-Model technology which guarantees in the various maneuver conditions optimal track stability and continuity. New tracks will be initiated automatically either based on data inputs from active radars or from passive sensors only. The tracking process has the capability to perform self-triangulation based on passive strobes from onboard sensors. Additionally, ESM reports from tactical data links are used together with reports from onboard sensors to perform multi-sensor cooperative passive tracking. Deghosting is done automatically.

The functions of the Tracking system are grouped in the following categories (see Figure 2):

- Data preprocessing
- Correlation/Association
- Track Update
- Track List Management
- Post processing

The preprocessing comprises functions like ordering of measurement data in a timeline related sequence, performing coordinate system transformation, etc.. In this processing bias compensation is performed for all input sensors.

In the correlation function, either the classical nearest neighbor algorithm or the advanced Multi-Hypothesis concepts are applied. Which concept will be applied is dependent on the actual complexity of the scenario in the vicinity of the current measurement/track position. Adaptive selection of the most suitable correlation algorithm will significantly reduce processor load. In doing so, maximum track continuity will be provided under all target conditions, and hence, track identification will be preserved through complicated target track crossing situations. Furthermore, ESM-based signature data and cross correlation between ESM- and kinematic data will also be used for the final report/track pairing. The operator can at any time either prohibit a selected correlation or enforce a correlation.

The track update function is executed for each track which has been associated to a target report. Depending on the type of the target report either a kinematic and/or a attribute update is performed for every model which is currently applicable to the track. Kinematic updating of active tracks is done by means of a Kalman component filter, whose peculiar feature is that updating of the state vector is performed for each measurement component separately. A major advantage of this Kalman component filter is that even under jammed or distorted conditions all available useful measurement information will be utilized. Attribute updating is performed by keeping record of attribute data of target reports incorporated into the track.

The Track List Management contains functions like track initiation, track deletion, track prediction and bias error estimation. Track initiation is performed on target reports for which no correlation was found. They will be initiated as tracks and labeled as potential track. Initiation of tracks will not only be performed on sensor data from active sensors but also on data from passive sensors. Track deletion will be applied to tracks, whose quality figure recedes below a certain threshold. These deletion thresholds automatically adapt to environment parameters and to the different track states. Track prediction is performed for the time when the next sensor update is expected. The predicted position is input to the correlation function the next time. The bias error estimation function analyzes measurement residuals of each sensor with respect to the system track. In order to maximize overall track quality and accuracy, possible offsets between all sensors are monitored and estimated continuously in background. If necessary, observed offsets are compensated automatically by an adaptive logic.

In the post processing, coordinate system transformations are performed to adapt the tracker to the external system. Finally, data is converted to external data formats.

In summary, the functions performed by the MSI-Tracking are:

- processing of input data from different types of sensors - Primary Radar, IFF, ESM, Links
- merge active and passive tracking (both cooperative and self triangulation) including sophisticated correlation and association logic. This makes use of geometric data and attributes. The correlation and association logic uses rules about identity indications from ID sources
- update each measurement component (Range, AZ, EL, Range Rate) separately, using a special form of Kalman Filter algorithm
- automatically associate of signature and attribute parameters (IFF, ESM, ECM, Link data) to tracks
- update attributes (IFF codes, ESM attributes, ECM attributes)
- compensate ownship motion
- automatic track initiation and track drop
- automatic maneuver detection
- measurement dropout coasting
- automatic detection & compensation of bias (registration) errors
- processing of operator initiated track commands
- determination of target environment (air, ground, surface) based on kinematics data

Upon reception of system control commands issued automatically by the MSI monitoring & control as part of MSI management SW, the tracking adapts its functions automatically to graceful degradation measures in order to prevent uncontrolled program behavior in case of special conditions (e.g. overload). Additionally, the MSI-Tracking function monitors sensor input data for plausibility in order to generate inputs for error logging.

2.3 The Multi-Sensor Identification System

The MSI Identification function has the capability to identify air, surface, and ground tracks. It will operate fully automatic and uses all available data of the available sensors as well as derived information and background information dependent on the confidence which can be given to the information sources. The system can handle different identification schemes in parallel (e.g., suited for either peace, tension, war states, contingency missions etc.). The identification schema is loaded as data during system initialization.

High flexibility in the ID process is achieved by providing the operator with several means to adapt the identification function to mission specific needs. Some of these means are:

- modification of the set of information to be used for identification,
- modification of mission data
- overriding of identification results.

The functions of the multi-sensor identification are based upon artificial intelligence concepts, which use a rule based artificial intelligence system. This rule-based system was developed by DASA ASD with the focus to be used in operational systems and give responses with minimum delay.

The MSI Identification function does provide the capability to assign track identities based on integrated sensor, communications and operator provided data. ID related information as for example conformance of tracks to flight plans, or platform identification by origin (IDBO), which on its own may not provide conclusive ID are combined in order to extract maximal benefit from the available sources of data. Conflict resolution is performed in case of contradictory data. Therefore, the MSI- Identification function will make maximum use of the available information to provide its results.

The MSI Identification function uses the information from different sources to determine the identity of MSI tracks. These sources are:

- 2D-position, altitude, speed and heading, their error values, environment category (air, surface, ground) and time of track update of the targets from MSI Track File
- ID related data from data links
- Mission data

All available information for the MSI Identification process is used in a most effective way to derive a unique target identification and classification for the environment categories air, surface, and ground. The identification is done automatically or by operator input. The manual ID assignment has priority over automatically determined ID. In case of manual ID assignment automatic ID determination will continue and MSI ID will report detected differences between automatic identification based on available information and the manually assigned ID.

The automatic identification process will evaluate all available identification information for every MSI track using “identification indicators”. These identification indicators will be combined into a track identity by an artificial intelligence (AI) supported combination process. Conflicts in the available identification information will be detected. The automatic system will provide conflict resolution functionality. In cases where conflict resolution is not possible operator alerts will be generated automatically. Possible ID conflicts with ID data from the data links are indicated to the operator. In case of detected severe ID-changes (e.g. from FRIEND to HOSTILE or vice versa) a manual ID assignment will be requested.

The MSI Identification function will provide rationale for its results to the operator. The complete MSI Identification process will be controlled in a flexible way by operator changeable “Adaptation Data”.

The incoming (live) sensor and communication data may be mixed with simulated data in order to train operators during real mission flights.

Upon reception of system control commands the MSI Identification adapts its functionality automatically to graceful degradation measures to prevent uncontrolled program behavior in case of special conditions (e.g. overload).

2.4 MSI Manager

The MSI Manager function will integrate the MSI Tracking and Identification functions. It will provide all necessary communication mechanisms for MSI Tracking and MSI Identification based on the Real Time Communication middleware.

The MSICP application software will use the Real Time Communication Layer and MC/MSIC System Software layers and provide CORBA 2.0 compliant interfaces for external communication and communication between major internal software components (cf. Figure 1).

An overall MSICP system control will be provided by the MSI Manager including system startup and shutdown mechanisms as well as the overall control of operational modes of the MSICP. The MSI Manager will also provide an overall system monitoring function. This function will provide all required MSICP system status data in regular manner to the MSICP external interfaces.

The MSICP will be responsible for redundancy support of MSI Tracking and MSI Identification.

The MSI Manager will be responsible for the overall computer load management within the MSICP. It will measure computer load, detect overload situations and activate the load adaptation functionality of the MSI Tracking and Identification function to prevent unpredictable behavior.

Within the MSI Manager and within MSI Tracking and Identification provisions for test functionality will be included, which can be activated by the MSI Software Test Bed. These provisions will be used during system testing and integration and may be used for maintenance activities in the software life cycle. These provisions will support:

- recording of external and internal MSICP interfaces
- logging of MSICP internal data for test and maintenance purposes.

The MSI Software Test Bed will include the functionality to make use of these provisions including the external interfaces.

3 SYSTEM TEST

During Test and Development the MSI Software Test Bed provided by DASA Airborne Systems will include all functionality needed to operate the MSICP in a test environment. It will additionally provide simulations of Mission Computer functionality as needed to run the MSICP in a test bed. The MSI Software Test Bed will simulate interfaces to the MSICP compatible to the MCP real time interfaces. Parts of this MSI Software testbed may also be used for maintenance purposes during the operational usage of the MSICP. Functionality and performance of the MSICP will be verified by a two stage approach. First, testing is performed via computer models. The Test and Development Support software contains a variety of representative scenarios and generates the inputs of all relevant sources. It also considers the sensor behavior that affects detection performance and accuracy of the measurements. The Test and Development Support Software (TADS) will include all features needed to generate the necessary data, and do the analysis of results. Second, the MSICP is tested by using recorded life data. The evaluation of the results is also performed by the TADS.

In the final qualification test run, the configuration data of the multi-sensor tracking and identification function will be optimized during real flight tests. This will finally verify the functions and the performance of the MSICP.

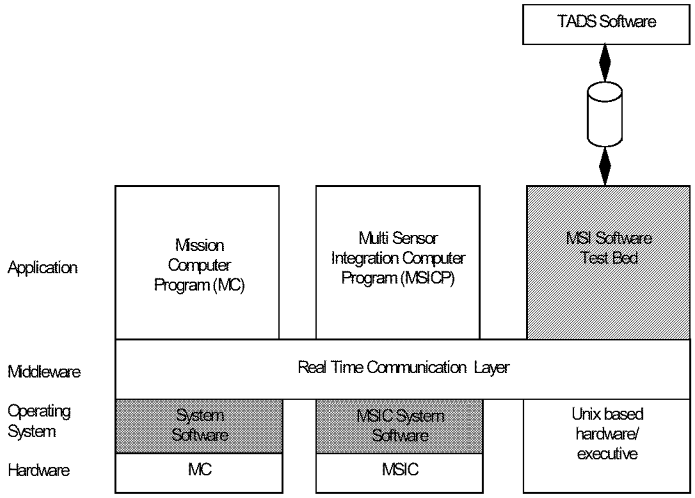

Figure 1: Software Layers (Test Configuration)

4 SUMMARY

In this article we have presented a brief overview of the DaimlerChrysler Multi-Sensor Integration System. It explains the requirements for the new system and its performance drivers as well as the concepts which were applied in the system design in order to match the practical requirements. Especially in the identification function a new dimension of flexibility is implemented to enable operators to cope with the changing real world situation.

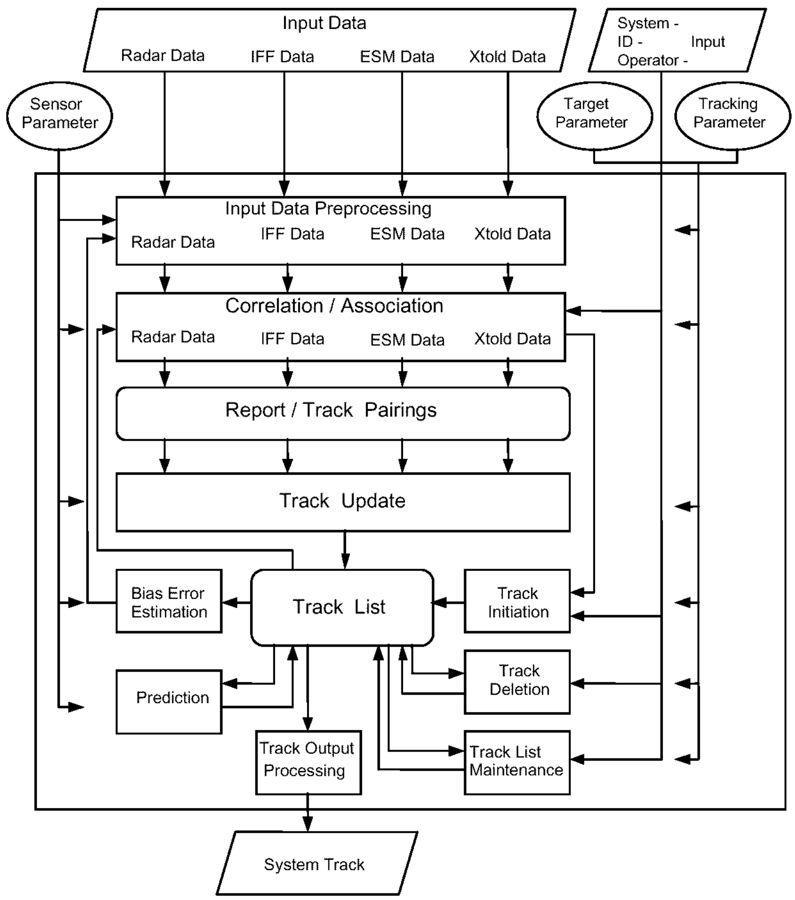

Figure 2: MSI Tracker